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Original Study

Stronger Impact of COVID-19 in Nursing Homes of a French Region During the Second Pandemic Wave



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A B S T R A C T

Keywords:
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Objectives: Quantify the effects of characteristics of nursing homes and their surroundings on the spread of COVID-19 outbreaks and assess the changes in resident protection between the first 2 waves (March 1 to July 31 and August 1 to December 31, 2020).

Design: An observational study was carried out on data on COVID-19 outbreaks extracted from a database that monitored the spread of the virus in nursing homes.

Setting and Participants: The study concerned all 937 nursing homes with >10 beds in Auvergne-Rhône-Alpes region, France.

Methods: The rate of nursing homes with at least 1 outbreak and the cumulative number of deaths were modeled for each wave.

Results: During the second (vs the first wave), the proportion of nursing homes that reported at least 1 outbreak was higher (70% vs 56%) and the cumulative number of deaths more than twofold (3348 vs 1590). The outbreak rate was significantly lower in public hospital-associated nursing homes than in private for-profit ones. During the second wave, it was lower in public and private not-for-profit nursing homes than in private for-profit ones. During the first wave, the probability of outbreak and the mean number of deaths increased with the number of beds ($P < .001$). During the second wave, the probability of outbreak remained stable in >80-bed institutions and, under proportionality assumption, the mean number of deaths was less than expected in >100-bed institutions. The outbreak rate and the cumulative number of deaths increased significantly with the increase in the incidence of hospitalization for COVID-19 in the surrounding populations.

Conclusions and Implications: The outbreak in the nursing homes was stronger during the second than the first wave despite better preparedness and higher availabilities of tests and protective equipment.

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anonymized and aggregated data obviated the need for participant consent. All data relevant to the study are included in the article or uploaded as supplementary information.

The authors declare no conflicts of interest.

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Solutions for insufficient staffing, inadequate rooming, and suboptimal functioning should be found before future epidemics.

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Since the declaration of the COVID-19 pandemic (World Health Organization, March 11, 2020: <https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19-11-march-2020>) up to the end of May 2022, the global number of reported cases reached 531,470,423, of which 6,318,391 deaths occurred. (<https://www.ecdc.europa.eu/en/geographical-distribution-2019-ncov-cases>, June 9, 2022).

During the first pandemic wave, nursing homes worldwide were places of high COVID-19 outbreak levels^{1–3} and COVID-19–related deaths. Indeed, by May 2020, across Europe, long-term care facilities, including nursing homes, reported 26% to 66% of all COVID-19–related deaths.⁴ However, Ioannidis⁵ elaborated that the excess risk of infection in nursing homes vs the general population was not seen in all countries during the first COVID-19 wave: in countries with high disease spread in the general population (eg, Belgium, United Kingdom, or Spain), the risk of being infected in a nursing home was 2 to 3 times higher than in the general population, whereas it was much lower in countries with low disease spread (eg, South Korea). This indicated that, at least during the first pandemic wave, disease onset in nursing homes was strongly linked with the spread of the SARS-CoV-2 virus in the surrounding population^{2,3,6–9} and that nursing homes were exposed to massive outbreaks facilitated by congregate living, frequent and close resident-caregiver contacts, and cognitive impairments that hampered the use of barrier gestures against the disease, in a context of shortage of staff, tests, and protective equipment.^{10–12} It appeared, thus, that reducing the spread of a highly contagious virus, such as SARS-CoV-2, in the general population is necessary to protect vulnerable residents of nursing homes.

Furthermore, to implement efficient infection prevention practices, it is essential to determine which facility structure or organization is effective in preventing infectious disease transmission and which strategies better control virus outbreaks in nursing homes.

During the second pandemic wave, the recourse to systematic testing, the availability of protective equipment, and the implementation of other infection control measures were thought able to reduce massive outbreaks and spreads of SARS-CoV-2 in nursing homes.

The present study was carried out to quantify the effect of the characteristics of the nursing homes and their surroundings on the introduction of COVID-19 into the facilities and the sizes of outbreaks, and assess the changes in resident protection between the first and the second pandemic wave using retrospective epidemiological surveillance data collected during the pandemic.

Methods

Nursing Home and Surrounding Characteristics

The study concerned all 937 nursing homes with >10 beds located in the Auvergne-Rhône-Alpes (ARA) region of France. This region is the second most important of Metropolitan France; it had 8,032,377 inhabitants in 2020 and includes 12 *Départements* (administrative areas) whose populations range between 142,811 and 1,876,051 inhabitants.⁹

In this study, the nursing homes were characterized by their “type” and “capacity.” The types considered were private for-profit, private not-for-profit, public hospital–associated, and public non–hospital-associated facilities. The capacity (ie, number of beds) ranged from 11 to 443 (Table 1).

The nursing home surroundings were characterized by the “external pressure of the disease” and the “population density.” The pressure was represented by the daily rate of persons hospitalized for COVID-19 per *Département*; ie, the number of persons hospitalized for COVID-19 (source: the COVID-19 specific national database <https://www.gouvernement.fr/info-coronavirus/carte-et-donnees>) divided by the population of the *Département* (source: projections for 2020 of national census data <https://www.insee.fr/fr/statistiques/2859843>). The population density around each nursing home was calculated as the mean of population densities (number of inhabitants per km²) of the nursing home location city and neighboring cities. The neighboring cities were those that share boundary points with the nursing home location city. They were determined using function `poly2nb` of the *spdep* package of R statistical software.

The level of outbreaks in the population of each *Département* during the 2 waves was characterized by the cumulative number of people hospitalized for COVID-19 and the cumulative hospital COVID-19–related deaths (source: <https://www.gouvernement.fr/info-coronavirus/carte-et-donnees>) (Supplementary Table 1).

Nursing Home Data

The data on COVID-19 outbreaks in the nursing homes were extracted from a specific database designed and maintained by Santé Publique France to monitor the spread of the virus in all medico-social facilities (cf. <https://www.gouvernement.fr/info-coronavirus/carte-et-donnees>).

All nursing homes of the ARA region that reported at least 1 suspected case with symptoms or a confirmed case in residents or staff members during the first or second pandemic wave (March 1 to July 31, 2020, or August 1 to December 31, 2020) were considered to have had an outbreak during that wave. Whenever a nursing home reported several outbreaks during any wave, only the date of symptom onset in the first disease case of the first outbreak was retained. In case of missing information, the date of symptom onset was imputed using a nearest neighbor imputation algorithm.⁹ This concerned 18.2% of facilities with outbreaks during the first wave (95 of 523) and 10.4% during the second wave (68 of 654).

The size of an outbreak was the cumulative number of deaths related to COVID-19. In nursing homes that reported several outbreaks during any wave, the number of deaths was cumulated over all outbreaks.

Statistical Analysis

Modeling the rate of nursing homes that reported at least 1 outbreak

The modeling was carried out for each pandemic wave using different time intervals per wave to take into account the change in COVID-19 incidence over the studied periods. A mixed Poisson regression model with random intercept on *Département* was used to quantify the effect of nursing home (and surrounding) characteristics on the rate of nursing homes having had an outbreak per time interval. The logarithm of the number of days in each time interval was introduced in the model as an offset. The capacity of a nursing home with >200 beds was set at 200 and any population density >1500 was set at 1500 inhabitants per km². Capacity was introduced in the model in a quadratic form using an orthogonal polynomial. Regarding the

Table 1
Nursing Home Characteristics, Overall and According to the Home Type, in the ARA (Auvergne-Rhône-Alpes) Region, France

| Nursing Home Characteristics | Type of Nursing Home | | | | |
|----------------------------------|----------------------|--------------------|------------------------|----------------------------|--------------------------------|
| | All Institutions | Private For-Profit | Private Not-For-Profit | Public Hospital-Associated | Public Non-Hospital-Associated |
| Number (%) | 937 (100) | 154 (16.4) | 318 (33.9) | 153 (16.3) | 312 (33.3) |
| <i>Division per Département*</i> | | | | | |
| Rhône | 159 (17.0) | 47 (30.5) | 72 (22.6) | 20 (13.1) | 20 (6.4) |
| Loire | 111 (11.9) | 19 (12.3) | 38 (12.0) | 16 (10.5) | 38 (12.2) |
| Isère | 108 (11.5) | 5 (3.3) | 47 (14.8) | 19 (12.4) | 37 (11.9) |
| Puy-de-Dôme | 99 (10.6) | 14 (9.1) | 20 (6.3) | 7 (4.6) | 58 (18.6) |
| Drome | 71 (7.6) | 17 (11.0) | 35 (11.0) | 13 (8.5) | 6 (1.9) |
| Ain | 67 (7.1) | 16 (10.4) | 18 (5.7) | 14 (9.1) | 19 (6.1) |
| Haute-Savoie | 66 (7.0) | 11 (7.1) | 10 (3.1) | 16 (10.4) | 29 (9.3) |
| Ardèche | 65 (6.9) | 7 (4.5) | 18 (5.7) | 18 (11.7) | 22 (7.0) |
| Savoie | 55 (5.9) | 5 (3.3) | 10 (3.1) | 13 (8.5) | 27 (8.6) |
| Allier | 48 (5.1) | 10 (6.5) | 14 (4.4) | 7 (4.6) | 17 (5.5) |
| Haute-Loire | 48 (5.1) | 1 (0.7) | 22 (6.9) | 5 (3.3) | 20 (6.4) |
| Cantal | 40 (4.3) | 2 (1.3) | 14 (4.4) | 5 (3.3) | 19 (6.1) |
| Capacity [†] | 80 (60–93) | 80 (64–92) | 75 (60–87) | 103 (76–152) | 79 (55–88) |
| <50 beds* | 129 (13.8) | 19 (12.3) | 44 (13.8) | 16 (10.5) | 50 (16.0) |
| 50–100 | 616 (65.7) | 116 (75.4) | 233 (73.3) | 52 (34.0) | 215 (68.9) |
| 100–150 | 132 (14.1) | 19 (12.3) | 37 (11.6) | 42 (27.4) | 34 (10.9) |
| 150–200 | 36 (3.8) | 0 (0) | 4 (1.3) | 27 (17.6) | 5 (1.6) |
| ≥200 | 24 (2.6) | 0 (0) | 0 (0) | 16 (10.5) | 8 (2.6) |
| Density [‡] | 248 (77–688) | 623 (235–1364) | 428 (106–999) | 194 (93–380) | 101 (37–450) |
| <100 inhab./km ² * | 293 (31.3) | 23 (14.9) | 75 (23.6) | 42 (27.5) | 153 (49.0) |
| 100–250 | 178 (19.0) | 18 (11.7) | 53 (16.7) | 49 (32.0) | 58 (18.6) |
| 250–500 | 140 (14.9) | 29 (18.8) | 47 (14.8) | 36 (23.5) | 28 (9.0) |
| 500–1000 | 149 (15.9) | 35 (22.7) | 63 (19.8) | 16 (10.4) | 35 (11.2) |
| 1000–1500 | 55 (5.9) | 16 (10.4) | 18 (5.6) | 5 (3.3) | 16 (5.1) |
| ≥1500 | 122 (13.0) | 33 (21.4) | 62 (19.5) | 5 (3.3) | 22 (7.1) |

*Number (column percentage).

[†]Number of beds in the nursing home, median (1st–3rd quartile).

[‡]Density of the surrounding population in number of inhabitants per km².

nursing home type, “private for-profit” was taken as the reference category.

The cumulative rate of hospitalization for COVID-19 over each wave was modeled in each *Département* using the 5-parameter nonlinear model of Brain and Cousens.^{9,13} The first derivative of the modeled curves returned the daily hospitalization rates in each *Département*. The mean hospitalization rate by time interval was calculated and introduced in the model to quantify the effect of the “external pressure” of the disease.

Modeling the cumulative number of COVID-19-related deaths

A zero-inflated negative binomial model was used to quantify the effect of nursing home (and surrounding) characteristics on the cumulative number of deaths in nursing homes that reported at least 1 outbreak. The analysis was carried out independently for each wave. Nursing home characteristics and population densities were introduced in the model in the same way as for the analysis of the outbreak rate. To quantify the effect of the “external pressure” of the disease, the peak of the daily hospitalization rate in the *Département* where the facility is located was introduced in the model. The peaks were extracted from the modeled curves of daily hospitalization rates per *Département* for each wave (Supplementary Table 2).

In a last model, the mean number of deaths was supposed to increase proportionally with the capacity. A comparison with the model that supposed a quadratic effect allowed assessing the way the effect of capacity deviates from the assumption of proportionality.

Predicted outbreak rates and COVID-19-related death numbers

A Monte-Carlo method was used to obtain predictions of outbreak rates and death numbers with 95% prediction intervals. From the final multivariate models, 1000 samples of the parameters drawn from the multivariate normal distribution of the estimated parameters were

used to obtain the distributions of the predicted outbreak rates and death numbers. The median, the 2.5, and the 97.5 percentiles of these distributions were retained as predicted values and used to build the 95% prediction intervals.

All analyses were carried out with R statistical software, version 3.6.1.¹⁴

Results

Nursing Home Characteristics

Among the 937 nursing homes of the ARA region, 318 (34%) were private not-for-profit, and 312 (33.3%) were public non-hospital-associated (Table 1). The nursing homes with the higher capacities were the public hospital-associated: 28% of them had ≥150 beds (median: 103 beds). In contrast, no private for-profit nursing home had ≥150 beds (maximum: 125 beds).

The types of nursing homes were related to the densities of the cities of location: 31.8% of private for-profit nursing homes were located in cities with densities of >1000 inhabitants per km², whereas 49.0% of public non-hospital-associated nursing homes were located in cities with densities <100 inhabitants per km².

Hospitalizations and Deaths Related to COVID-19 in the Population

In the ARA region, the cumulative number of hospitalizations for COVID-19 and the cumulative number of hospital COVID-19-related deaths were practically 3 times higher (2.7 and 2.8, respectively) during the second wave vs the first wave (Supplementary Table 1). This increase was observed in all the *Départements* of the ARA region. The peak of the daily hospitalization rate was also higher during the

second wave vs the first wave in all but 1 *Département* (Supplementary Table 2).

Outbreaks in the Nursing Homes During the First and Second Pandemic Waves

Among the 937 nursing homes of the ARA region, the proportion that reported at least 1 outbreak was higher during the second than during the first wave (70% vs 56%). This proportion was higher during the second than during the first wave in all *Départements* of the ARA region, except 2 (Supplementary Table 3). Only 4% (6 of 154) of private for-profit nursing homes declared no outbreak during any of the 2 waves. This proportion reached 20% (31 of 153) in public hospital-associated nursing homes (Figure 1). Among the nursing homes that did not declare outbreaks during the first wave, the proportion that declared outbreaks during the second wave ranged between 62% and 89%, according to the type of nursing home. This proportion was also high in nursing homes that declared an outbreak during the first wave (58% to 80%).

During the 2 waves, the outbreak rate was significantly lower in public hospital-associated nursing homes than in private for-profit ones (Supplementary Table 5, Table 2). This rate was also significantly lower in public non-hospital-associated and private not-for-profit nursing homes than in private for-profit ones during the second wave.

During the first wave, the predicted probability of outbreak increased together with the nursing home capacity (Figure 2; $P < .001$). During the second wave, this probability increased with the capacity

until nearly 80 beds ($P < .001$) to remain stable afterward ($P = .002$). The outbreak rate was not influenced by the location population density during the first wave but increased significantly with that density during the second wave (Table 2). The effects of the “external pressure” of the disease on the outbreak rate were similar during the 2 waves; the outbreak rate increased significantly with the increase in the incidence of hospitalization for COVID-19 in the surrounding population.

Cumulative Number of Deaths Related to COVID-19

Among the nursing homes that reported at least 1 outbreak, the proportion that reported at least 1 death was higher during the second than during the first wave (70% vs 46%), and the cumulative number of deaths was a little more than twofold higher (3348 vs 1590). The proportion of nursing homes with at least 1 death as well as the cumulative number of deaths increased during the second vs the first wave in all *Départements* of the ARA region (Supplementary Table 4). Among the nursing homes that declared at least 1 outbreak during the 2 waves, 39% had no deaths due to COVID-19 and 37% had a cumulative number of deaths ≥ 6 in at least 1 of the 2 waves. The cumulative number of deaths was not associated with the type of nursing home in either wave (Supplementary Table 5, Table 3). The mean predicted number of deaths increased with the capacity of the nursing homes during each of the 2 waves (Figure 2, $P < .001$). During the second wave, the increase in the number of deaths seemed to be less than what would be expected (under the

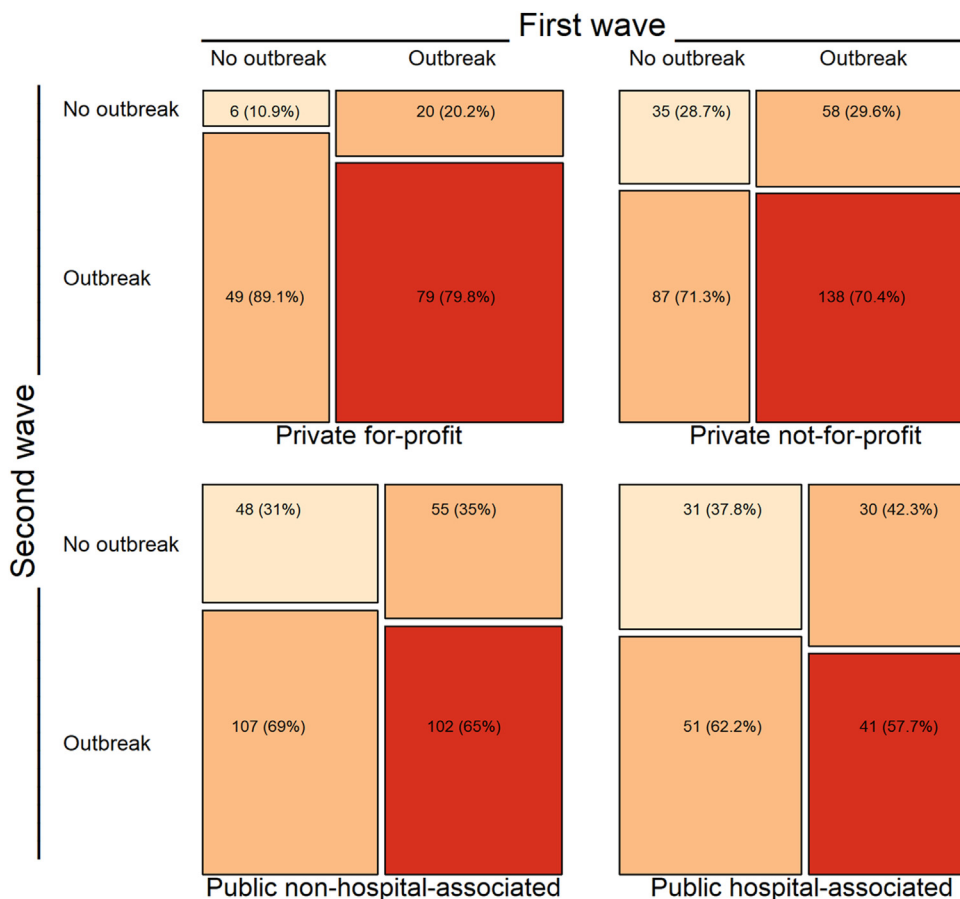


Fig. 1. Nursing homes and COVID-19 outbreaks. Number of nursing homes in the ARA (Auvergne-Rhône-Alpes) region (France) according to the type and occurrence of COVID-19 outbreaks during the first and second waves of the pandemic. The proportions of nursing homes with and without outbreaks during the second wave according to the occurrence or not of an outbreak during the first wave are also given (column percentages).

Table 2
Estimates of the Effects of the Characteristics of the Nursing Homes and Their Surroundings on the Rate of Nursing Homes With COVID-19 Outbreak: Results of the Mixed Poisson Regression Modeling of the Outbreak Rate in the ARA (Auvergne-Rhône-Alpes) Region, France

| Nursing Home Characteristics | First Wave | | Second Wave | |
|--------------------------------|-----------------------|---------|----------------------------|---------|
| | March 1–July 31, 2020 | | August 1–December 31, 2020 | |
| | HR [95% CI] | P Value | HR [95% CI] | P Value |
| Type | | .0001 | | .002 |
| Private for-profit | 1 | | 1 | |
| Private not-for-profit | 1.09 [0.85–1.39] | .5 | 0.73 [0.59–0.91] | .006 |
| Public hospital-associated | 0.56 [0.40–0.80] | .001 | 0.57 [0.42–0.77] | .0002 |
| Public non-hospital-associated | 0.78 [0.59–1.02] | .07 | 0.72 [0.56–0.92] | .008 |
| Density* | 0.99 [0.94–1.04] | .64 | 1.06 [1.02–1.11] | .008 |
| Incidence of hospitalization † | 1.19 [1.07–1.33] | .002 | 1.15 [1.09–1.22] | <.0001 |

HR, hazard ratio; CI, confidence interval.

*Density of the surrounding population in number of inhabitants per km². The effect is given for a doubling of the density.

†Mean hospitalization rate for COVID-19 in the surrounding population per time interval. The effect is given for a doubling of the hospitalization rate.

hypothesis of proportionality) in nursing homes with ≥100-bed capacities (Supplementary Figure 1).

The cumulative number of deaths increased significantly with the location population density and the hospitalization peak in the surrounding population during each of the 2 waves (Table 3).

Discussion

At the end of the first 2 pandemic waves, nearly 90% of the nursing homes of the ARA region were affected by COVID-19. The proportion of facilities with at least 1 outbreak was higher during the second vs

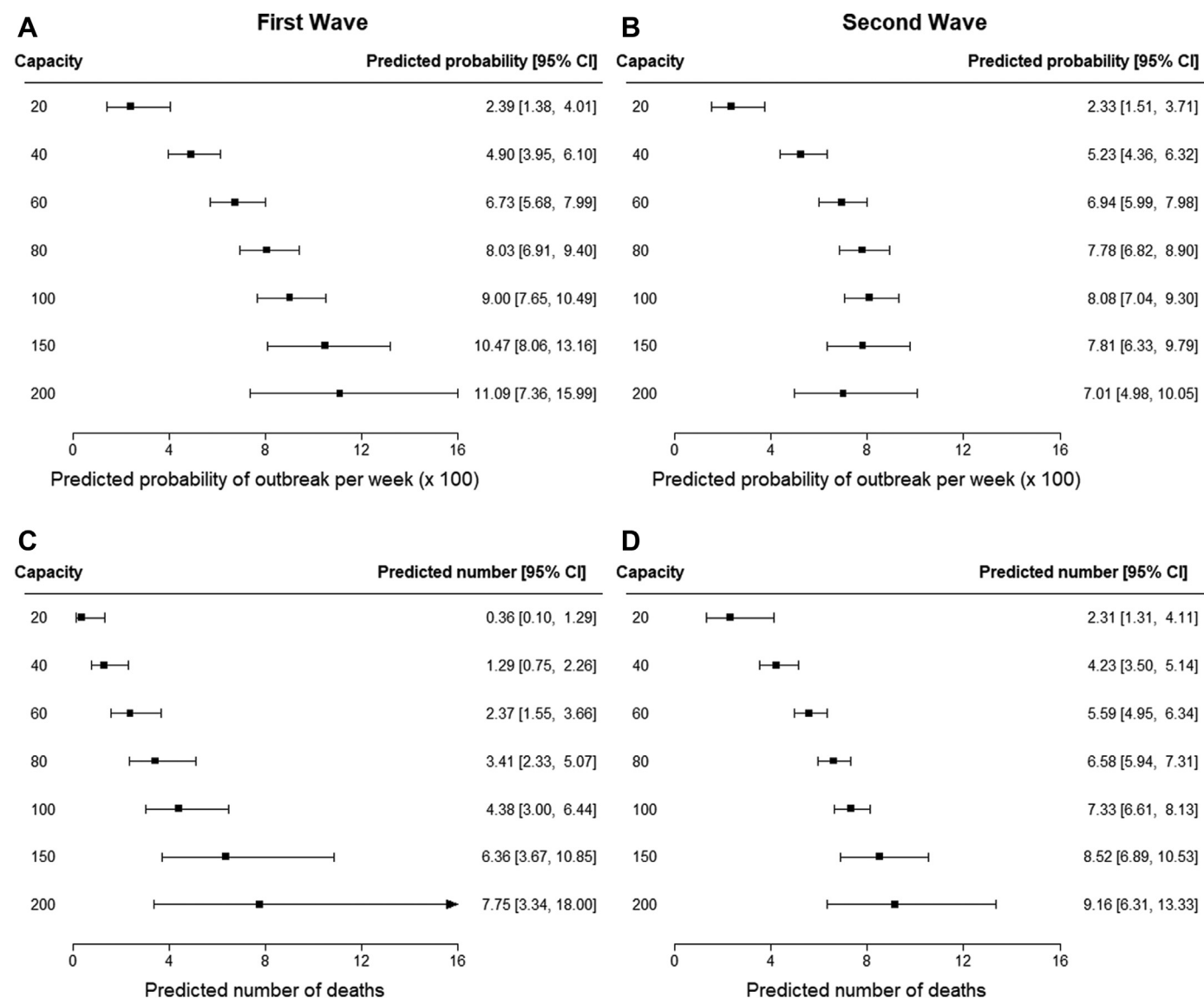


Fig. 2. COVID-19 outbreaks and deaths. Predicted probabilities of outbreak per week and predicted number of deaths in the nursing homes during the first and second pandemic waves according to the capacity (number of beds) in the ARA (Auvergne-Rhône-Alpes) region, France (from the multivariate models).

Table 3
Estimates of the Effects of the Characteristics of the Nursing Homes and Their Surroundings on the Cumulative Number of COVID-19–related Deaths in Homes Having Reported at Least 1 Outbreak: Results of the Zero-Inflated Negative Binomial Regression Modeling of the Number of Deaths in the ARA (Auvergne-Rhône-Alpes) Region, France

| Nursing Home Characteristics | First Wave | | Second Wave | |
|--------------------------------------|-----------------------|---------|----------------------------|---------|
| | March 1–July 31, 2020 | | August 1–December 31, 2020 | |
| | HR [95% CI] | P Value | HR [95% CI] | P Value |
| <i>Nursing home type</i> | | .50 | | .59 |
| Private for-profit | 1 | | 1 | |
| Private not-for-profit | 0.98 [0.61–1.57] | .92 | 0.95 [0.75–1.20] | .66 |
| Public hospital-associated | 0.82 [0.42–1.61] | .57 | 1.10 [0.80–1.51] | .55 |
| Public non-hospital-associated | 1.29 [0.73–2.27] | .38 | 0.91 [0.71–1.18] | .48 |
| <i>Density*</i> | 1.13 [1.02–1.25] | .02 | 1.07 [1.02–1.12] | .0003 |
| <i>Incidence of hospitalization†</i> | 1.64 [1.29–2.08] | <.0001 | 1.62 [1.25–2.11] | .002 |

HR, hazard ratio; CI, confidence interval.

*Density of the surrounding population in number of inhabitants per km². The effect is given for a doubling of the density.

†Peak of hospitalization for COVID-19 infection in the *Département* of location. The effect is given for a doubling of the hospitalization peak.

the first wave and the cumulative number of deaths was slightly more than twofold higher, in accordance with the importance of community outbreak in the ARA region during the second wave. The higher level of outbreaks in the population of the ARA region during the second wave is illustrated by cumulative numbers of hospitalizations and deaths nearly threefold higher during the second wave vs the first (Supplementary Tables 1 and 2). A moderate increase in the cumulative number of COVID-19–related deaths in the nursing homes was also observed in whole France: 14,116 deaths during the first wave¹⁵ vs 14,855 during the second.¹⁶ This may be explained by the strong impact of the first wave lockdown on the spread of the disease in the population; thus, in the nursing homes,⁹ not to mention that, during the second wave, social distancing measures (ie, night curfews; closing of cultural events, bars, and restaurants; mask wearing in all public spaces) were less stringent. Besides, the lower number of COVID-19–related deaths during the first vs the second wave may be partly explained by fewer attributions to the disease due to shortage of tests, thus the lack of disease evidence. This was illustrated by Schultz et al.¹⁷ who showed in old people living in care homes in England an increase in non-COVID-19 risk of death during the first wave vs before the pandemic and no increase during the second wave. These results are in favor of an underestimation of the number of COVID-19–related deaths during the first wave.

Overall, during the second wave, the nursing homes of the ARA region were strongly affected despite the availability of protection equipment and the generalization of testing. However, the increase in the number of COVID-19–related deaths was not observed in all European countries. For example, (1) among old people of care homes in England, the peak of COVID-19 mortality during the second wave was lower than during the first wave¹⁷; (2) still in England, among COVID-19–related deaths, the proportion occurring in nursing homes was approximately 31% during the first wave but only 20% during the second wave¹⁸; and (3) similar decreases (by 30%) were observed in other countries such as Finland or Germany.¹⁸ The latter decreases may be explained by more efficient protection measures against infection in the populations with the highest mortality risks, which was not the case in France where the proportion of COVID-19–related deaths occurring in nursing homes decreased only slightly by 7% (47% to 39%).^{15,16} In the ARA region, both the probability of an outbreak and the sizes of the outbreaks were linked to the spread of the disease in the surrounding population and the strength of this link was very similar during the 2 waves. This indicates that, in the region, the measures taken to control COVID-19 outbreaks and spread in the nursing homes during the second wave had limited effects.

During the 2 waves, the rate of outbreak was higher in private for-profit than in public nursing homes; it was also higher than in private not-for-profit nursing homes during the second wave. Previous studies have shown a higher risk of disease introduction in for-profit nursing homes than in not-for-profit and public nursing homes.^{8,19–21} In a study by Zhu et al.¹⁹ on nearly 8000 nursing homes in the United States, private for-profit nursing homes showed not only higher risks of disease outbreak but also higher risks of death and higher virus transmission ability. In Victoria, Australia, private for-profit nursing homes owned by large chains had higher risks of outbreak and wider outbreaks during the second wave.²⁰ Furthermore, a meta-analysis has shown that for-profit nursing homes had lower quality of care than not-for-profit ones,²² and several other studies showed that there is a link between low quality of care assessed before the pandemic and high rates of cases and deaths in nursing homes.^{23–27} In France, private for-profit nursing homes have the lowest staff-resident ratios and higher difficulties to recruit permanent caregivers than other types of nursing homes; they often recourse to interim staff.^{28,29} This chronic shortage of qualified staff and the high personnel turnover may partly explain the vulnerability of for-profit facilities to epidemic outbreaks.

During the second wave, the outbreak rate increased with the nursing home capacity but remained stable at capacities >80 beds. Furthermore, the number of deaths in nursing homes experiencing at least 1 outbreak tended to increase less than expected at capacities >100 beds. One explanation is that nursing homes with high capacities are organized in several independent units. An inverse relationship between facility capacity and number of cases or deaths was even found by some studies.^{18,22} It seems that the structure and organization of the nursing homes is more associated with the occurrence and spread of an outbreak than the number of beds. In a study by Zhu et al.,¹⁹ an increase in the area per bed and the proportion of single rooms were linked with decreases in the spread of COVID-19, the number of cases, and the number of deaths. Previously, a study by Brown et al.³⁰ found a positive relationship between nursing home crowding index and the number of COVID-19 cases or deaths. An organization of nursing homes in small units with sufficient dedicated and qualified staff, single bedrooms and bathrooms, and protected outdoor space seems to be an ideal design for outbreak control and improvement of residents' quality of life.³¹

One limitation of this study is that an imputation of the date of disease onset of the first case was made in 18% (first wave) and 10% (second wave) of the nursing homes with outbreaks, due to missing dates. Of these cases, some could have been erroneously attributed to the wrong wave; however, this is thought to have only minor impacts on the results. Another limitation of the present work is that the

spread of COVID-19 in the nursing homes was quantified by the cumulative number of deaths instead of the cumulative number of cases. This choice was made because the number of confirmed cases was dependent on heterogeneous testing strategies within a context of test shortage, especially during the first wave. The number of deaths related to COVID-19 seemed to be a more robust criterion.¹⁷ Another limitation is the lack of information on the characteristics of the residents; indeed, case-mix differences between nursing homes are likely to bias the estimates of the effects of the nursing homes' characteristics. In particular, the lower outbreak rate in public and private not-for-profit nursing homes vs private for-profit ones may be partly explained by case-mix differences between nursing home types. A survey carried out in 2017 in French nursing homes (<https://www.cnsa.fr/actualites-agenda/actualites/la-situation-des-etablissements-dhebergement-pour-personnes-agees-dependantes-ehpad-en-2017>) has shown that the dependency level and the level of care needs of the residents were slightly lower in public non-hospital-associated and private not-for-profit nursing homes than in private for-profit nursing homes, but similar in public hospital-associated and private for-profit nursing homes.

Conclusions and Implications

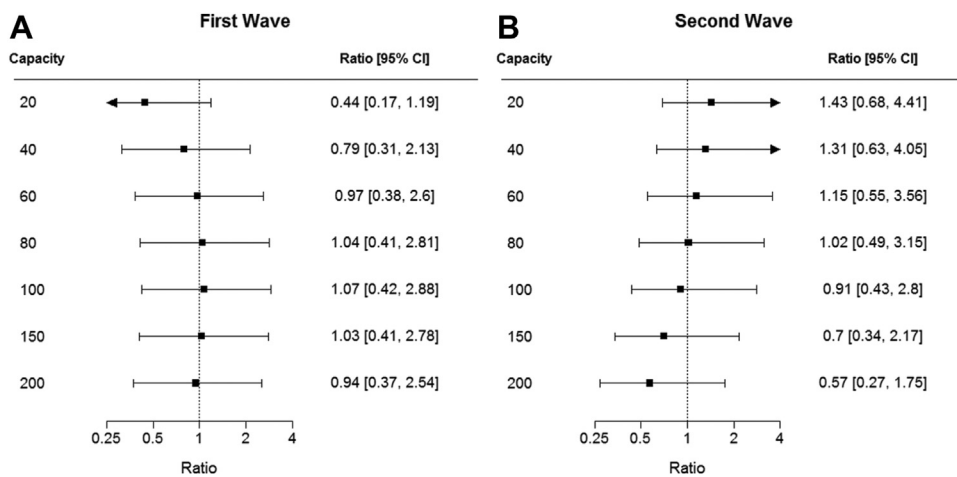
The results of the present study allow concluding that COVID-19 outbreak in the nursing homes of the ARA region was stronger during the second wave than during the first despite much better availability of protective equipment and tests and the experience acquired during the first wave. Besides, in addition to disease outbreak and spread control, it seems important to find solutions to the chronic shortage of caregivers and rethink the structure and functioning of nursing homes so as to improve their preparedness to deal with future epidemics.

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Supplementary Fig. 1. Predicted number of COVID-19–related deaths. Ratios of the predicted number of COVID-19–related deaths (from the quadratic modeling of the capacity effect) to the predicted number of COVID-19–related deaths under the assumption of a proportional effect of the capacity in nursing homes of the ARA (Auvergne-Rhône-Alpes) region of France during the first and second epidemic waves.

Supplementary Table 1

COVID-19 Hospitalizations and Deaths in the ARA Region

| | Number of Hospitalizations | | Number of Hospital Deaths | |
|-------------------------|----------------------------|-------------|---------------------------|-------------|
| | First Wave | Second Wave | First Wave | Second Wave |
| <i>Département</i> | | | | |
| Rhône | 4485 | 8573 | 683 | 1229 |
| Loire | 1390 | 3377 | 249 | 610 |
| Haute-Savoie | 1085 | 2934 | 167 | 464 |
| Isère | 955 | 5012 | 155 | 834 |
| Drome | 729 | 1565 | 133 | 277 |
| Ardèche | 674 | 1064 | 114 | 200 |
| Ain | 642 | 1609 | 106 | 280 |
| Savoie | 515 | 1993 | 75 | 393 |
| Allier | 265 | 1401 | 42 | 281 |
| Puy-De-Dôme | 264 | 1777 | 44 | 306 |
| Haute-Loire | 159 | 893 | 18 | 137 |
| Cantal | 73 | 367 | 10 | 50 |
| <i>Whole ARA region</i> | 11,236 | 30,565 | 1796 | 5061 |

Cumulative number of COVID-19–related hospitalizations and deaths during the first epidemic wave (March 1–July 31, 2020) and the second epidemic wave (August 1–December 31, 2020) in the *Départements* of the ARA (Auvergne-Rhône-Alpes) region of France.

Supplementary Table 3

COVID-19 Outbreaks in the Nursing Homes of the ARA Region

| Area | At Least 1 Wave | First Wave | Second Wave |
|-------------------------|-----------------|----------------|----------------|
| <i>Département</i> | | | |
| Haute-Savoie | 63/66 (95.5) | 48/66 (72.7) | 53/66 (80.3) |
| Loire | 103/111 (92.8) | 62/111 (55.9) | 91/111 (81.9) |
| Isère | 98/108 (90.7) | 64/108 (59.3) | 82/108 (75.9) |
| Ain | 60/67 (89.6) | 41/67 (61.2) | 41/67 (61.2) |
| Haute-Loire | 43/48 (89.6) | 28/48 (58.3) | 33/48 (68.8) |
| Rhône | 142/159 (89.3) | 107/159 (67.3) | 114/159 (71.7) |
| Savoie | 48/55 (87.3) | 28/55 (50.9) | 38/55 (69.1) |
| Allier | 41/48 (85.4) | 19/48 (39.6) | 34/48 (70.8) |
| Ardèche | 55/65 (84.6) | 40/65 (61.5) | 30/65 (46.2) |
| Puy-De-Dôme | 81/99 (81.8) | 39/99 (39.4) | 68/99 (68.7) |
| Drome | 55/71 (77.5) | 36/71 (50.7) | 46/71 (64.8) |
| Cantal | 28/40 (70.0) | 11/40 (27.5) | 24/40 (60.0) |
| <i>Whole ARA Region</i> | 817/937 (87.2) | 523/937 (55.8) | 654/937 (69.8) |

Cumulative number (percent) of nursing homes having reported at least 1 COVID-19 outbreak during the first epidemic wave (March 1–July 31, 2020) or the second epidemic wave (August 1–December 31, 2020), in the *Départements* of the ARA (Auvergne-Rhône-Alpes) region of France.

Supplementary Table 2

Peaks of Hospitalization Rate in the ARA Region

| <i>Département</i> | First Wave* | Second Wave* |
|--------------------|------------------|--------------------|
| Rhône | 67.5 [66.7–68.4] | 66.7 [64.5–68.5] |
| Loire | 58.8 [58.0–59.6] | 85.3 [83.5–87.1] |
| Drome | 57.7 [56.8–58.7] | 60.3 [59.0–61.7] |
| Ardèche | 42.4 [39.3–45.7] | 66.1 [64.167.8] |
| Haute-Savoie | 41.6 [41.1–42.1] | 83.6 [82.0–85.3] |
| Savoie | 39.2 [38.1–40.2] | 101.1 [98.9–103.1] |
| Ain | 29.1 [28.5–29.7] | 56.1 [55.0–57.3] |
| Haute-Loire | 22.7 [21.8–23.5] | 92.1 [89.4–94.4] |
| Isère | 18.9 [18.6–19.1] | 69.0 [67.2–70.8] |
| Allier | 18.8 [18.0–19.7] | 66.9 [65.9–67.9] |
| Cantal | 13.4 [12.9–13.9] | 31.0 [29.0–31.4] |
| Puy-De-Dôme | 12.9 [12.4–13.6] | 43.9 [42.8–45.0] |

Peaks of the daily hospitalization rate related to COVID-19 during the first epidemic wave (March 1–July 31, 2020) and the second epidemic wave (August 1–December 31, 2020) in the population of the *Départements* of the ARA (Auvergne-Rhône-Alpes) region of France.

*Rate per 1 million person-days [95% CI].

Supplementary Table 4

COVID-19 Deaths in the Nursing Homes of the ARA Region

| | Number of Nursing Homes With at Least 1 Death | | | Number of Deaths | |
|-------------------------|---|----------------|----------------|------------------|-------------|
| | At Least 1 Wave | First Wave | Second Wave | First Wave | Second Wave |
| <i>Département</i> | | | | | |
| Haute-Savoie | 55/63 (87.3) | 26/48 (54.8) | 46/53 (86.8) | 185 | 412 |
| Rhône | 123/142 (86.6) | 72/107 (67.3) | 83/114 (72.8) | 623 | 522 |
| Loire | 81/103 (78.6) | 34/62 (54.8) | 69/91 (75.8) | 220 | 579 |
| Isère | 77/98 (78.6) | 28/64 (43.8) | 64/82 (78.1) | 168 | 504 |
| Savoie | 33/48 (68.8) | 12/28 (42.9) | 28/38 (73.7) | 33 | 243 |
| Drome | 37/55 (67.3) | 12/36 (33.3) | 29/46 (63.0) | 66 | 120 |
| Ardèche | 36/55 (65.5) | 19/40 (47.5) | 22/30 (73.3) | 127 | 167 |
| Ain | 37/60 (61.6) | 18/41 (43.9) | 26/41 (63.4) | 93 | 213 |
| Haute-Loire | 25/43 (58.1) | 6/28 (21.4) | 22/33 (66.7) | 9 | 148 |
| Puy-De-Dôme | 44/81 (54.3) | 9/39 (23.1) | 42/68 (61.8) | 46 | 256 |
| Allier | 21/41 (51.2) | 4/19 (21.1) | 20/34 (58.8) | 19 | 155 |
| Cantal | 6/28 (21.4) | 1/11 (9.1) | 5/24 (20.8) | 1 | 29 |
| <i>Whole ARA region</i> | 575/817 (70.4) | 241/523 (46.1) | 456/654 (69.7) | 1590 | 3348 |

Number (percent) of nursing homes having reported at least 1 COVID-19–related death and cumulative number of COVID-19–related deaths in nursing homes that reported at least 1 outbreak during the first epidemic wave (March 1–July 31, 2020) or the second epidemic wave (August 1–December 31, 2020), in the *Départements* of the ARA (Auvergne-Rhône-Alpes) region of France.

Supplementary Table 5

Results of Univariate Modeling

| Events | First Wave | | Second Wave | |
|--|------------------|---------|------------------|---------|
| | HR [95% CI] | P Value | HR [95% CI] | P Value |
| <i>COVID-19 outbreaks</i> | | | | |
| Type of nursing home | | .0011 | | <.001 |
| Private for-profit | 1 | | 1 | |
| Private not-for-profit | 1.05 [0.82–1.35] | | 0.70 [0.56–0.87] | |
| Public hospital–associated | 0.66 [0.48–0.90] | | 0.54 [0.41–0.71] | |
| Public non–hospital-associated | 0.77 [0.59–1.00] | | 0.63 [0.50–0.79] | |
| Density* | 1.10 [1.00–1.21] | .0517 | 1.14 [1.08–1.20] | <.001 |
| Hospitalization incidence [†] | 1.30 [1.12–1.52] | .0021 | 1.24 [1.14–1.34] | <.001 |
| <i>COVID-19-related deaths</i> | | | | |
| Type of nursing home | | .2503 | | .0794 |
| Private for-profit | 1 | | 1 | |
| Private not-for-profit | 0.75 [0.47–1.19] | | 0.95 [0.75–1.21] | |
| Public hospital–associated | 0.96 [0.53–1.72] | | 1.25 [0.94–1.66] | |
| Public non–hospital-associated | 0.64 [0.39–1.05] | | 0.89 [0.70–1.13] | |
| Density* | 1.22 [1.07–1.39] | .0027 | 1.12 [1.05–1.20] | .0012 |
| Hospitalization peak [‡] | 2.25 [1.62–3.11] | <.001 | 2.17 [1.47–3.19] | <.001 |

HR, hazard ratio; CI, confidence interval.

Results of univariate modeling of the rate of nursing homes that reported at least 1 outbreak and the cumulative number of COVID-19–related deaths during each COVID-19 wave.

*Density of the surrounding population expressed as the number of inhabitants per km². The effect is given for a doubling of the density.

[†]Mean hospitalization rate for COVID-19 in the surrounding population per time interval. The effect is given for a doubling of the hospitalization rate.

[‡]Peak of hospitalization for COVID-19 infection in the *Département* of location. The effect is given for a doubling of the hospitalization peak.